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TVA

Tennessee
Valley
Authority

Division of
Energy Conservation
& Rates

Heat Pump Water Heater Field Test

Final Report
Fall 1981

ORIGINAL

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64

HEAT PUMP WATER HEATER

FIELD TEST

Final Report

Fall 1981

Division of Energy Conservation and Rates

Load Management Branch

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1. INTRODUCTION

In order to determine the benefits, performance, reliability, and costs associated with heat pump water heaters, the Tennessee Valley Authority (TVA) conducted a 2-year field test. The test utilized two types of units tested in nine homes. Part of this test was in cooperation with the Department of Energy's (DOE) testing program for heat pump water heaters.

Included in this introduction section is a background subsection which summarizes the major historical events leading to this field test. A brief list of the field test's purposes follows.

The second section provides the reader with a detailed description of various aspects of the field test. These include project description, equipment characteristics, participant selection, data collection methods, and evaluation methodologies.

This report's third section addresses the effects of heat pump water heaters on total energy and total demand with respect to water heating. Some insight into the reliability of heat pump water heaters is also found in this section. Finally, there is a discussion of customer reaction to heat pump water heater performance.

The fourth section of this report contains a review of heat pump water heater field tests conducted by other utilities across the country. The final subsection is a brief summary and status update of future TVA projects with heat pump water heaters.

1.1 Background:

Heat pump water heaters are not a totally new concept. In the 1950's, two firms produced heat pump water heaters for consumer use. Factors such as low energy costs, high material costs, and basic heat pump design problems contributed to the lack of acceptance of the early units.

The concept experienced a rebirth in the latter half of the 1970's. The passage of 2 decades had produced an entirely different technical and economic situation. Energy costs had risen sharply and electricity was no longer cheap and abundant. Conservation of resources and energy had become a principle goal of utilities and consumers.

Basic heat pump technology in 1975 was superior to that of the 1950's. Improvements and experience over the years had produced a dependable heat pump system. Public acceptance of heat pumps in general was more positive than it had been during the early days of development. With general public awareness of the need for curtailing energy consumption and stronger incentives to the consumer produced by increased costs, new emphasis was placed on the development of heat pump water heaters.

In 1976, Energy Utilization Systems (EUS) of Pittsburgh, Pennsylvania, developed a heat pump water heater (TEMCOR) utilizing a condenser tube positioned inside the storage tank. EUS received $5,000 in funding for the development of this unit from the National Rural Electric Cooperative Association's Research and Technological Development Committee.

While EUS was developing a unit in which the condenser was immersed in the tank, E-Tech, Incorporated, of Atlanta, Georgia, was developing a heat pump water heater which pumped water from an existing tank to a condenser coil and then back to the tank. E-Tech named their unit the Efficiency II.

In May 1977, EUS was employed by the DOE Office of Buildings and Community Systems to develop and test the TEMCOR heat pump water heater. The project consisted of a 12-month test of 100 TEMCOR units and was carried out by 20 cooperating utilities across the country. TVA, 1 of the 20 cooperating utilities, purchased 4 complete TEMCOR water heating systems and 1 retrofit-type unit. In addition, because of its commitment to energy conservation and load management, TVA also elected to purchase and test 5 Efficiency II units from E-Tech.

1.2 Purpose of Test:

In order to determine the benefits, performance, reliability, and costs associated with heat pump water heater technology, TVA conducted a 2-year field test of E-Tech and EUS heat pump water heating systems. The test had the following four principle objectives:

(1) Determine the performance and reliability of heat pump water heater systems.

(2) Determine achievable energy savings and demand reductions.

(3) Determine consumer acceptance and economics.

(4) Determine the overall acceptability of the concept as an energy conservation and load management alternative.

2. EXPERIMENT DESIGN

2.1 Project Description:

The Heat Pump Water Heater Field Test was a 2-year field test which began in June 1979 and was completed in May 1981. The test was conducted in conjunction with a cooperating power distributor and local homeowners selected by the participating distributor.

Homeowners were given the opportunity to purchase the systems at a reduced price or have the test equipment removed and replaced with the original equipment at the conclusion of the test. All maintenance, installation, and removal/restoration costs were assumed by TVA.

The participating distributor was responsible for homeowner/consumer contact, equipment installation, and data collection. TVA reimbursed the distributor for associated expenses, provided technical assistance, and processed and analyzed data.

2.2 Cooperating Distributor:

TVA selected a participating distributor from a list of distributors expressing interest in the project. The selected distributor, the Electric Board of Russellville, Alabama, serves approximately 3,500 residential consumers and is located in northwestern Alabama, approximately 20 miles south of Muscle Shoals. Russellville has 3,620 heating degree days and 2,000 cooling degree days. The applicable residential rate as of April 2, 1981 is RS-7 with a customer charge of $2.45, an energy charge of 3.903/kWh for the first 500 kWh, and 4.217/kWh for any consumption above 500 kWh.[1]

2.3 Participating Consumers:

The Russellville Electric Board conducted an informal survey to solicit interested participants for the field test. Participation was restricted to homeowners with electric heating and a suitable location for the heat pump water heater. Ten homeowners who met the above criteria were selected to participate. Water service to all the test homes is provided by the Russellville Water Department.

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1. Residential consumers in TVA's service area are billed under 1 of 12 residential rate schedules (RS-1 through RS-12). The rate used in Russellville (RS-7) is the average level in the Valley.

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Listed below are some of the pertinent facts about the consumers involved in the test.

EUS Participants:

Customer	Family Size	Home Size (ft^2)	Location of Unit
1	3	2,000	Basement
2	4	4,000	Basement
3	4	3,000	Basement
4	4	2,100	Basement
5*	2	2,000	Crawlspace

*Retrofit Unit

E-Tech Participants:

Customer	Family Size	Home Size (ft^2)	Location of Unit	Capacity of Existing Water Heater (gallons)
6	3	1,800	Utility Room	40
7**	3	1,800	Basement	52
8	3	2,100	Basement	52
9	3	1,512	Crawlspace	42
10	2	1,344	Utility Room	52

**Unfinished Basement with Dirt Floor

2.4 System Designs:

The EUS TEMCOR heat pump water heater (Figure 1) was a self-contained water heating system. It consisted of a MOR-FLO tank with two resistance elements and the heat pump equipment. The heat pump components were contained in circular metal housing on top of the tank, thus providing a smooth transition and compact design. The specifications of the unit were as follows:

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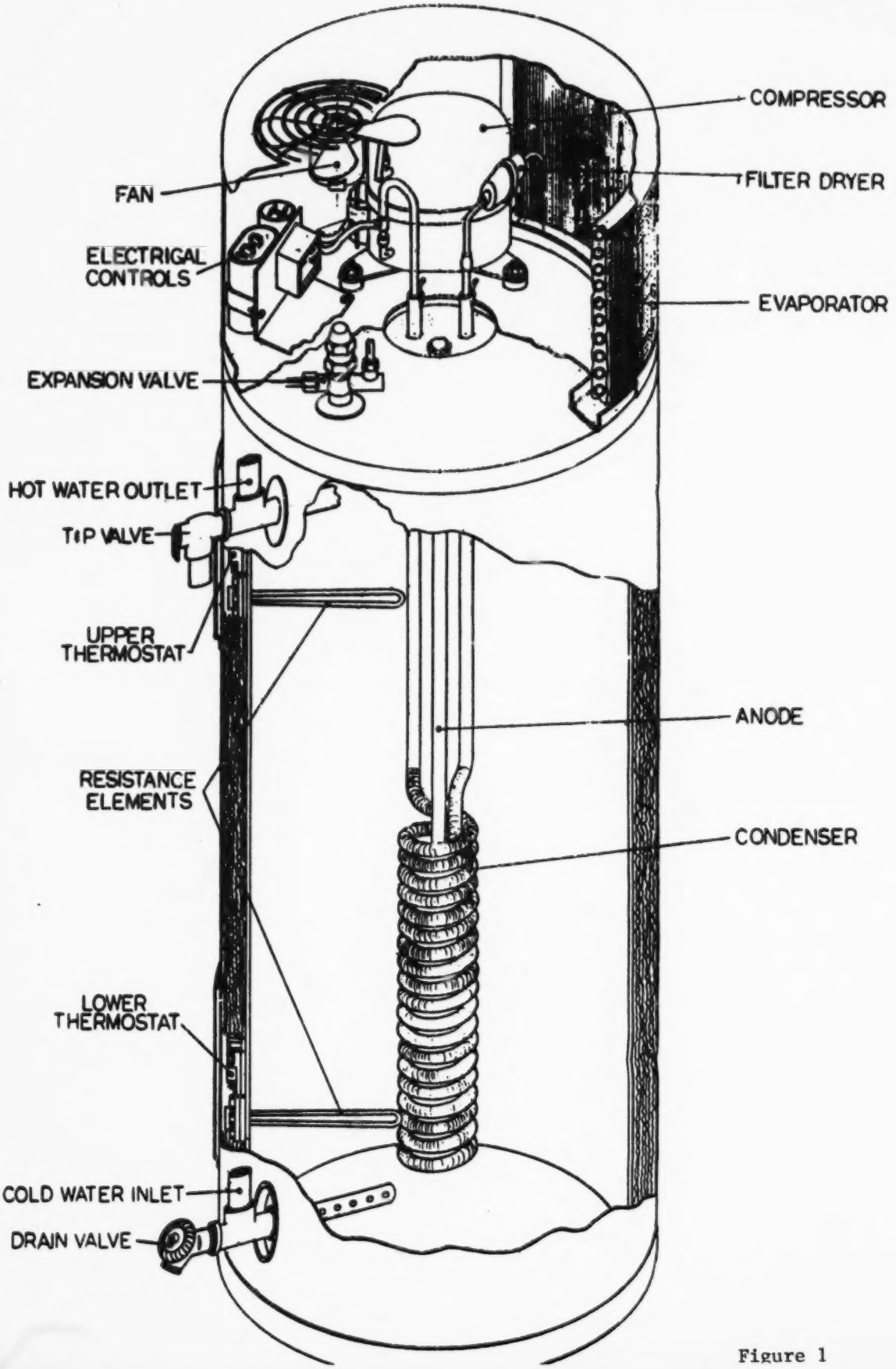

Figure 1

Figure 1

Capacity of tank	-	82 gallons
Compressor horsepower	-	2/3 horsepower with R12 charge
Compressor voltage	-	230 volts
Height	-	65 inches
Diameter	-	25 inches
Weight	-	330 pounds
Expansion valve	-	thermostatic, rated 1/2-ton R12
Fan	-	1/30 horsepower, 230 volts

The condenser was a chimney type made of tin-plated copper. The coil was 3/4-inch double copper tubing with fluting between the two tubes and on the outer surface. The space between the tubes provided a barrier between the water in the tank and the circulating refrigerant. This annular area was filled with colored water and sealed with a pressure relief cap to prove an indication of a breach in either tube wall.

The TEMCOR unit had a low-temperature cutoff switch which took the compressor out of service when the ambient temperature dropped below 47 degrees Fahrenheit. When the compressor was disconnected, the water heating was done by the top resistance element. The compressor returned to service when the ambient temperature reached 52 degrees Fahrenheit.

The EUS retrofit unit consisted of a heat pump unit mounted on top of the existing water heater and a condenser inserted into the tank. Insulated risers piped the refrigerant between the condenser and the compressor. The condenser was placed in the tank through the hole left by the removal of the lower resistance element. A 3/4-horsepower compressor was used in the retrofit unit.

For the purpose of gathering data in the DOE test, the EUS unit was modified to operate in two modes. In the resistance mode, water heating was accomplished solely through the use of the two resistance elements. In the heat pump mode, primary heating was done by the heat pump cycle with quick recovery backup by the upper resistance element.

The E-Tech Efficiency II (Figure 2) was an add-on unit for existing water heaters that was specifically targeted for "do-it-yourself" retrofit applications. The unit was connected to an existing tank with flexible hoses. Water was pumped from the bottom of the tank and returned to the top of the tank. The unit consisted of a compressor, evaporator coil, fan, water pump, condenser coil, expansion device, and flow control valve.

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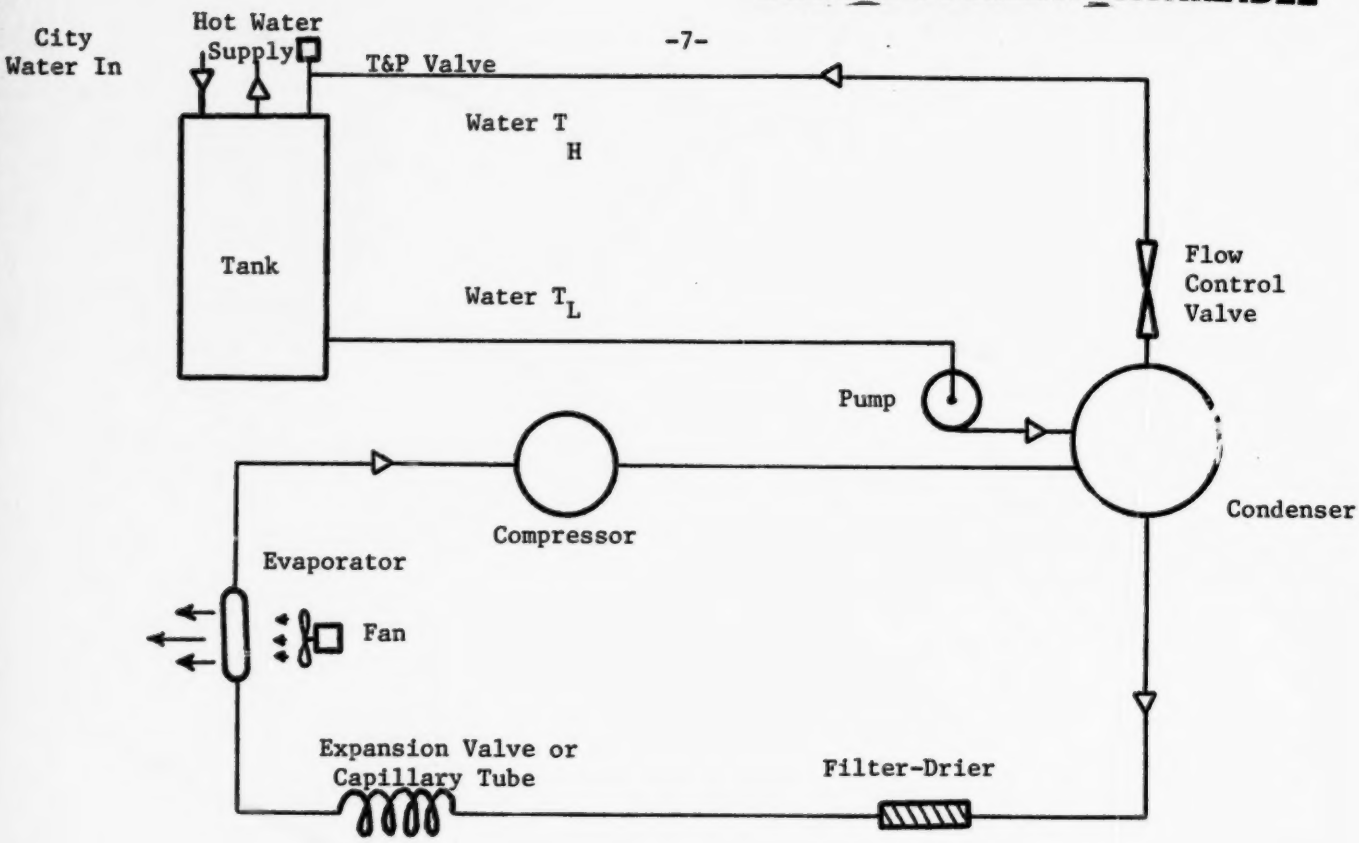

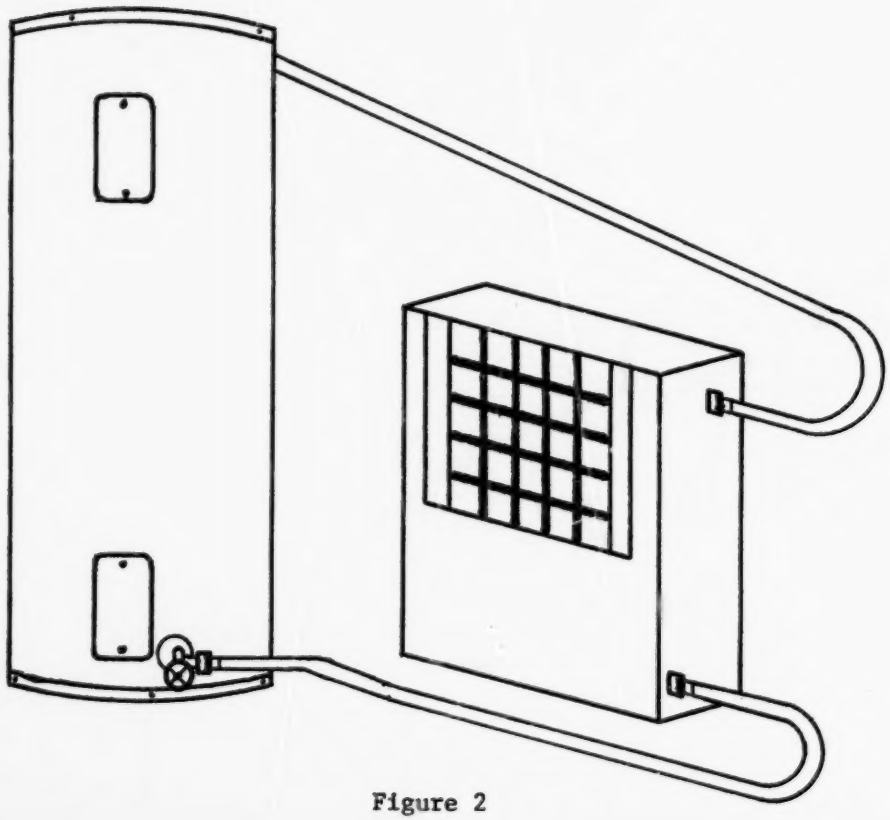

Figure 2

The general specifications of the Efficiency II were as follows:

Figure 2

Compressor	-	1 horsepower, 115 volt
Dimensions	-	18 inch by 10 inch by 25 inch
Weight	-	85 pounds
Fan	-	1/15 horsepower
Pump	-	1/40-horsepower magnetic drive

The condenser coil was produced from two copper tubes (water and refrigerant) wound into a helical coil. The water line and refrigerant line were 1/2 inch and 5/16 inch in diameter, respectively. Outlet water temperature from the unit was kept above 115 degrees by the modulating valve. Flow was varied to produce hot water of a consistent temperature.

Thermostat control was achieved by attaching a 24-volt thermostat to the lower portion of the tank. This thermostat activated the heat pump water heater when the temperature of the tank dropped below 120 degrees Fahrenheit. Although the unit was switched off when the bottom of the tank reaches 130 to 135 degrees Fahrenheit, the average tank temperature was about 140 degrees Fahrenheit. No evaporator freezing protection was included in the standard control circuitry; however, a freeze protection circuit is available as an addition to the unit.

During installation of the E-Tech units, the existing resistance elements were switched off. However, they remained in place and were available for emergency use.

2.5 Data Collection:

2.5.1 Instrumentation: In order to determine the energy savings produced by the heat pump water heaters, submetering packages were installed in each participating consumer's home. Each of the homes was equipped with a TVA submetering package and a water meter. In addition, the EUS homes had a metering panel provided by EUS.

The TVA submetering package consisted of a General Electric PDM-76 4-channel magnetic tape demand recorder and two watthour meters equipped with pulse initiators. One meter monitored the total electrical consumption of the home, while the other measured energy used by the water heating system.

The metering package supplied by EUS consisted of five watthour meters, a timeclock, switching relays, and a strip chart record. This package provided the data from which EUS was to evaluate the heat pump water heaters for DOE. These EUS packages were removed at the end of the 12-month DOE/EUS test period. The TVA metering packages remained in the EUS homes for the duration of the test.

A magnetic drive water meter was installed in the supply line to the water heater. Readings from this meter provided data on the number of gallons of hot water used each month.

2.5.2 Procedure: The magnetic tapes were changed each month. At that time, visual readings were taken from the watthour meters and the water meters.

During the first 12 months of the test, additional readings were taken at homes with the installed EUS units. The timeclock and switching relays changed the unit from one mode of operation to the other. Initially, the EUS heat pump water heaters were switched from resistance to heat pump mode and back again on a daily cycle. EUS determined that this method did not give a fair representation of the water heating abilities of the unit. The heat pump mode produced higher water temperatures in the tank so that when the switch was made to the resistance mode, the resistance elements did not have to supply as much energy as they normally would. In order to minimize this problem, the cycle of mode shifting was changed to a weekly pattern. At the end of the first 12 months of testing, the EUS units were placed on continuous heat pump operation.

The watthour meters were EUS/DOE-designated M1 through M5. The type of information collected by each meter was as follows:

M1 - Water heater during resistance mode

M2 - Water heater during heat pump mode

M3 - Top element during heat pump mode

M4 - Space heating/air-conditioning during heat pump mode

M5 - Space heating/air-conditioning during resistance mode

The strip chart recorder on the EUS panel recorded the ambient air temperature and the outlet water temperature from the water heater. This was accomplished with the use of a thermocouple suspended near the unit and a second thermocouple attached to the hot water pipe. Also, one EUS home was equipped with a second strip chart recorded to monitor inlet water temperature.

Readings from the five EUS meters and the strip chart tapes were collected each month for 12 months and forwarded to EUS. Readings from the TVA metering panels and water meters were supplied each month to both E-Tech and EUS for evaluation.

2.6 Evaluation Methodology:

2.6.1 Energy Reduction Analysis Methodology:

Each month as the data was returned from the field, basic analysis was performed to estimate the performance of the units with respect to energy reduction. Although certain test parameters were discounted, the methods provide an indication of the unit's performance compared to that of a conventional resistance water heater.

Initially, the different operating schedules of the two types of heat pump units required different assumptions and analytical methods for determining energy reduction. However, the calculation to estimate the energy that would have been consumed by a resistance water heater was common to both the EUS and E-Tech systems. This estimate was calculated from the amount of water used by each unit during each month. The following equations and constants were used:

$$Q = \frac{(M)(Cp)(\Delta T)}{3{,}412 \text{ Btu/kWh}} + SL$$

Q = Energy (kWh)

X = Gallons of water used (gal)

M = X (8.33 lb/gal)

Cp = Specific heat of water (1 Btu/lb^{o}F)

ΔT = Temperature change (^{o}F)

SL = Standby losses

The temperature change (ΔT) would normally be calculated by subtracting the inlet water temperature from the water heater output water temperature. However, since the necessary equipment was not available to measure these temperatures, estimates were necessary for the calculation.

The Russellville Water Department provided water temperature data that was used as a proxy for inlet temperature. Although strip charts were used to obtain inlet and outlet temperatures on the EUS unit during the DOE portion of the test, the charts obtained were forwarded directly to EUS and not available for

our analysis. The amount of correspondence depends on the temperature changes that occur between the utility and the homeowner in the piping system. These changes were considered to be minimal; therefore, the Russellville Water Department's temperatures were used to estimate inlet temperature. Figure 3 shows the utility water temperature with respect to the month of the year. The hot water outlet temperature was uniformly estimated to be 140 degrees Fahrenheit.

Standby losses were estimated from water heater industry data. The following equation was used:

$$\text{Energy loss/month} = \frac{(\text{heat loss/ft}^2)(\text{area of tank})(24 \text{ hours/day})(365 \text{ days/year})}{(12 \text{ months/year})}$$

Using industry data, the subsequent calculations were made.

Energy Losses Per Month:

E-Tech - 40-42 gallons - 114 kWh/month

50-52 gallons - 120 kWh/month

EUS - 82 gallons - 88 kWh/month

In the case of the EUS unit, this estimate was based on the fact that the EUS tank is described as "an 82-gallon energy saver electric water heater tank." It was assumed that this tank, therefore, met ASHRAE 90-75 standards. Test data from EUS, however, indicates that the standby losses are higher. An increase in the standby losses will increase the estimated savings slightly.

In the case of the E-Tech units, a direct comparison was made between the estimated normal resistance consumption and the consumption of the heat pump water heater. The consumption of the heat pump water heater was subtracted from the estimated normal resistance consumption. This quantity was called the estimated savings. When this quantity was divided by the estimated normal consumption, a percent of savings was determined.

Because the EUS units employed a "flip-flop" method of operation during the first 12 months, calculations for the EUS units involved other assumptions. The amount of water heated during each method of operation (heat pump and resistance) was assumed to be equal due to the equal division of time allotted to each mode of operation. Based on this assumption, the energy use of the heat pump water heater was doubled and then compared to the total water consumption. Energy consumption in the heat pump mode consisted of both the energy for the heat pump and the

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Utility Water Temperature Versus Month

Based on data from Russellville water utility

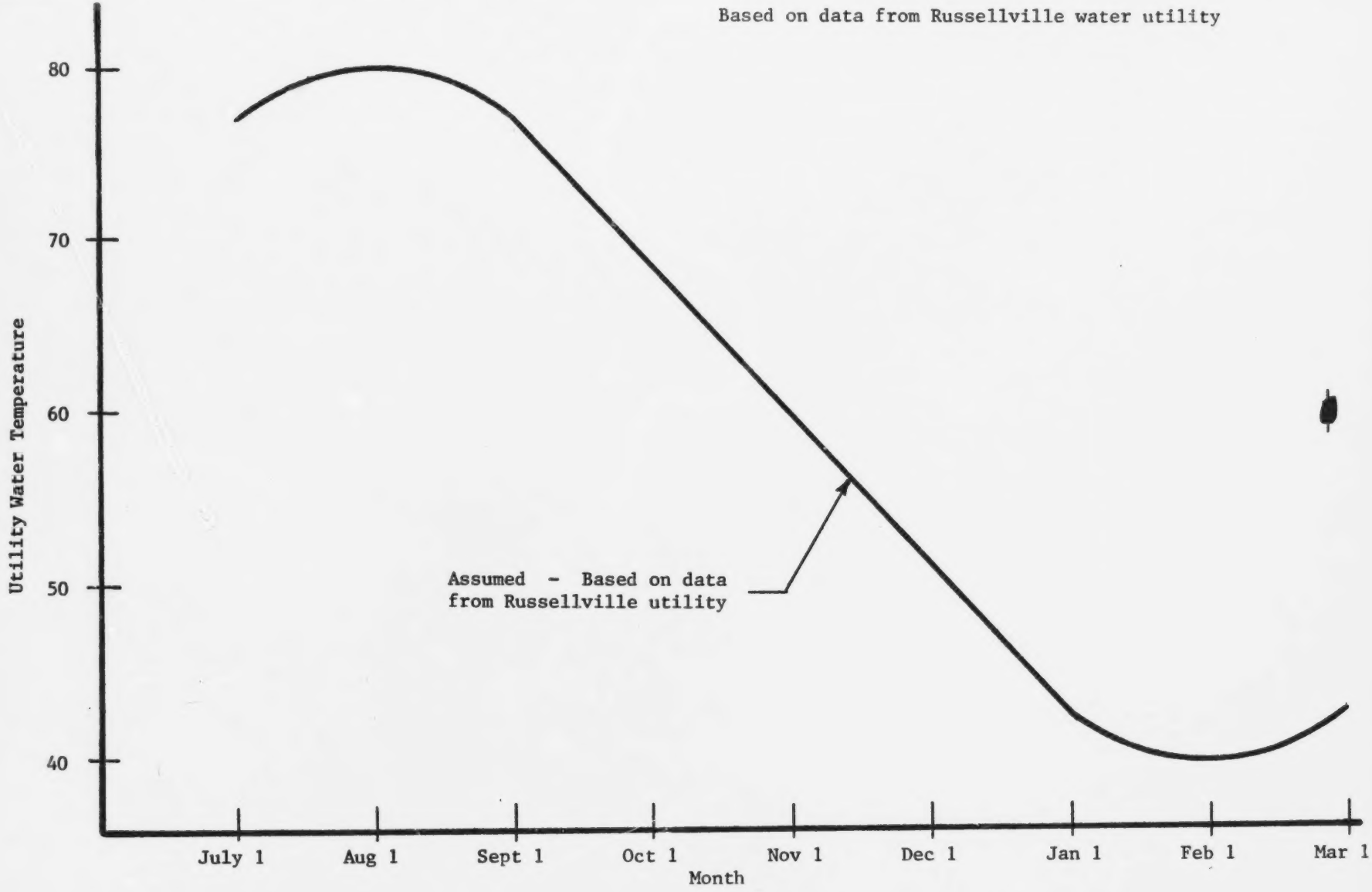

Figure 3

energy consumed by the backup resistance element. The same procedures were used to determine estimated normal resistance consumption, estimated savings, and percentage savings.

The estimated savings for each type of unit were totaled each month and compared to the totals of the estimated normal resistance consumption. This provided an average percentage of savings for each type of heat pump unit; however, all units were not included in the average. Units that were known to have an equipment malfunction were excluded. The average savings for the two types of units represent the average energy savings experienced during this test. Savings for TVA area consumers may differ but it is believed these differences would be slight.

Another indicator of the savings from the heat pump water heaters was the ratio of gallons of water used each month to the energy consumed by the heat pump water heaters. This ratio can then be compared to data on conventional resistance water heaters. Values for resistance units range from 3 gallon/kWh to 6 gallon/kWh.[2]

Piping losses were not considered in the calculations due to an unavailability of data; therefore, the savings estimated are slightly conservative. Piping losses are believed to be small and hence, have a minor effect on the test results.

2.6.2 Peak Reduction Analysis Methodology: One important item of interest, with respect to heat pump water heaters, is their effect on the overall TVA load curve. To determine this effect, the load requirements for heat pump and resistance water heaters must be compared. Hourly load observations were used to construct curves to reflect heat pump water heater demand versus normal resistance water heater demand during a typical day for the four seasons of the year.

The data used to represent the heat pump water heaters was obtained from the portion of the 2-year test between April 1980 and May 1981. No attempt was made to adjust the analysis for the EUS mode cycling, so the EUS data is omitted from some of the comparisons before fall 1980. The resistance (standard) water heater data came from tests conducted in four areas of

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2. This information is based on data from a TVA-conducted test on hot water usage ("End-Use Study of Domestic Hot Water - EPRI/TVA/CEPB"). The 3- to 6-gallon/kWh range was caused by variations in intake water temperature, required hot water temperature, standby losses, and piping losses.

the Tennessee Valley for the period April 1980 through March 1981.[3] The resistance sample is comprised of about 350 households in Huntsville, Alabama; Cleveland, Tennessee; Jackson, Tennessee; and a rural area on the central Kentucky-Tennessee border.

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3. TVA's "Four Community Water Heater Space Conditioning Test."

3. RESULTS

3.1 Equipment Reliability:

During the course of the test several problems arose. These problems can be divided into three general types: those pertaining to the test equipment, those associated with installation and location, and those related to instrumentation.

3.1.1 Test Units: The first difficulty encountered was indicated by poor performance data and complaints from the homeowner. Because of delivery delays, the EUS retrofit unit was installed 3 months subsequent to the other units and remained in operation for only 3 months. During that period of time, none of the data showed savings compared to conventional water heating. The homeowner complained about the excessive energy consumption of the unit and that it ran constantly. After two service calls failed to alleviate the problem, the homeowner requested that the unit be removed or repaired. The local utility decided to remove the retrofit unit.

The remaining EUS units were found to have malfunctions due to refrigerant leaks and improper charges. (Leaks were found in 2 units and all 4 were improperly charged.) Soldered connections in the refrigerant lines had developed small leaks. These leaks were attributed to the low production level and the manufacturing process at the time of assembly, transporation, and compressor vibration. The leaks were repaired and the systems recharged in January 1980. Later production EUS units include a shock-absorbing loop in the refrigerant line; however, the prototype test units did not.

A major problem with an E-Tech heat pump water heater occurred in February 1980. The temperature in one of the installation basements fell below the recommended 45 degree Fahrenheit level. This caused the condensate on the unit's evaporator to freeze, which rendered the heat pump useless. After freezing, the unit had to be manually switched to resistance operation when the homeowner complained of "no hot water." Because the unit had no low-temperature protection, the unit remained in the resistance mode until it was manually returned to heat pump operation.

The attachment of the thermostat to the water tank posed another problem for all of the E-Tech units. The thermostat installation procedure did not produce a satisfactory connection with the tank. The procedure relied solely on pressure from the surrounding insulation to keep the thermostat in contact with the tank. Excess energy consumption was the result when the thermostat became detached from the tank. Because the thermostats did not control the units properly, they ran too

long. The problem was repaired and E-Tech has developed a better method of affixing the thermostat to the water heater tank which utilizes the mounting clips of the original thermostat and should prevent reoccurrence of this problem.

One E-Tech unit was removed from service when a leak in the refrigerant system through the water flow control valve resulted in a dramatic drop in performance. It was replaced with a new model of current production which no longer uses a refrigerant actuated flow valve.

Despite these problems, the heat pump water heaters in the test functioned with a reasonable degree of reliability. A certain number of prototype "bugs" were expected. All major complications were noted by the manufacturers, and in each case, steps were taken to correct the deficiencies when future units were produced.

3.1.2 Location: A problem developed in the Number 10 installation that is not attributed to equipment failure or design. The E-Tech unit in this home was installed in a small utility room measuring approximately 8 feet by 8 feet. Although the entire unit was replaced because of poor performance data, the installation never provided consistent data. This inconsistency was attributed to a lack of air circulation when the door to the utility room is closed. This problem was due to an unsuitable location for the unit.

3.1.3 Instrumentation: Instrumentation problems were minimal with the only problem being a malfunctioning timer. Because of the timer problem, one EUS system was not switched from one mode to the other. This did not inconvenience the homeowner but did result in the loss of several months of data.

3.2 Performance Data Results:

3.2.1 Energy Savings Implications: Using the methodology described previously, monthly savings for each unit were calculated. Table 1, which follows, provides a list of the average monthly savings for each type of unit. After 23 months of data collection, the EUS units and E-Tech units have demonstrated average savings of 45 percent and 52 percent, respectively. Taken together, these percentages show an average energy savings of 49 percent for this field test. The monthly data and average annual data from each installation are listed in the appendix. Units that experienced malfunctions were excluded from the averages.

3.2.2 Peak Load Reduction Implications: Figures 4 through 7 depict the average electrical loads required by heat pump and resistance water heaters during each hour of a typical weekday.

Table 1

SUMMARY OF ENERGY SAVINGS

Period Ending	EUS Units		E-Tech Units	
	kWh	%	kWh	%
07/13/79	195	46	284	66
08/13/79	195	47	287	66
09/13/79	187	45	293	67
10/12/79	200	45	336	66
11/13/79	238	46	357	61
12/13/79	283	46	309	54
01/14/80	421	50	444	57
02/13/80	310	43	259	50
03/13/80	339	49	215	40
04/14/80	369	49	256	46
05/14/80	262	44	329	57
06/15/80	241	48	295	58
07/18/80	175	42	242	59
08/21/80	-	-	260	57
09/18/80	171	48	245	63
10/16/80	195	40	258	58
11/26/80	402	49	412	54
01/06/81	238	29	144	27
02/06/81	317	42	159	32
03/10/81	312	43	167	34
04/13/81	355	44	162	36
05/18/81	281	43	171	41
Average Savings/Month	271	45	267	52
Average Savings/Year	3,252	45	3,204	52

HEAT PUMP WATER HEATER VS STANDARD WATER HEATER

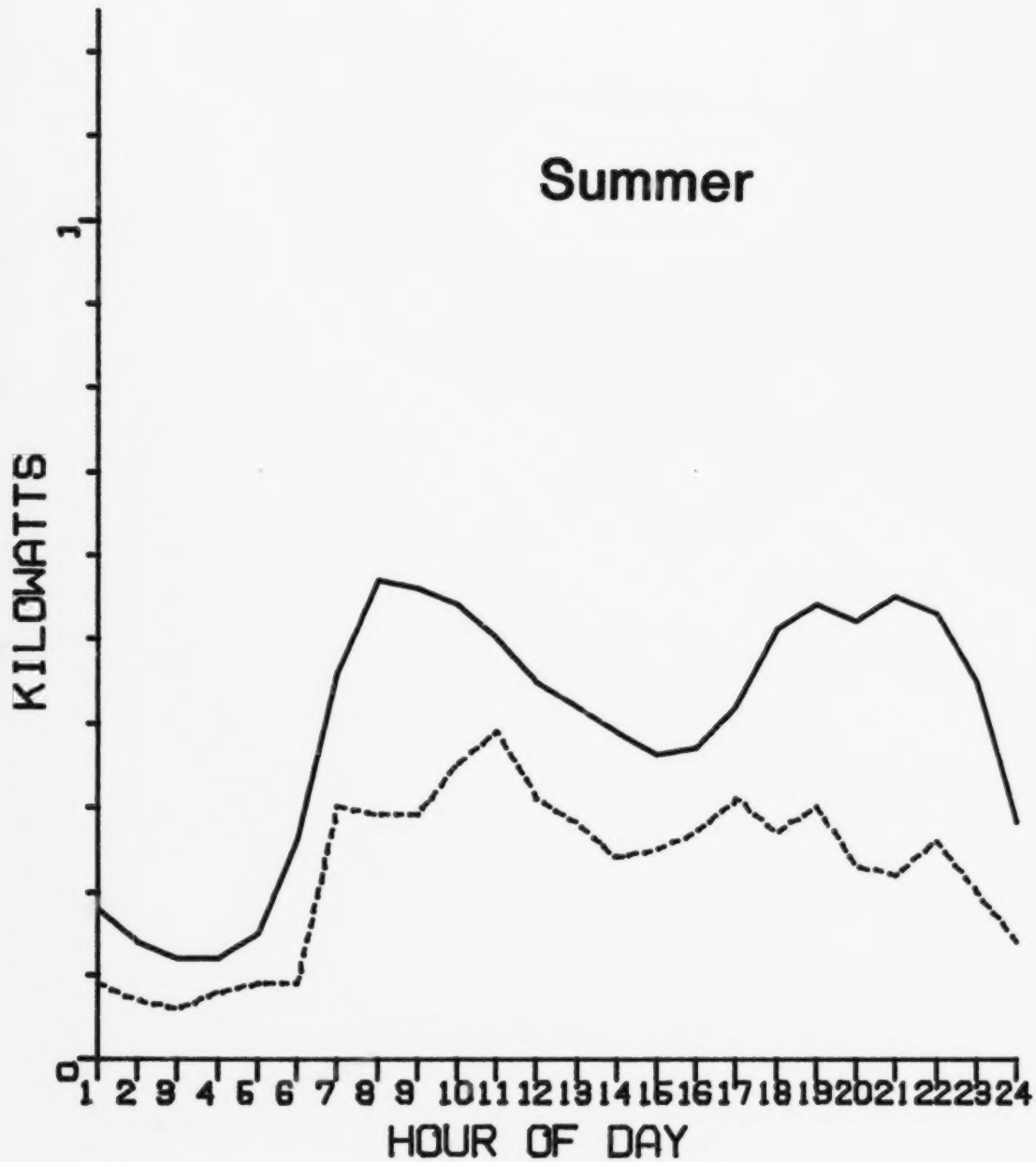

Figure 4

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HEAT PUMP WATER HEATER VS STANDARD WATER HEATER

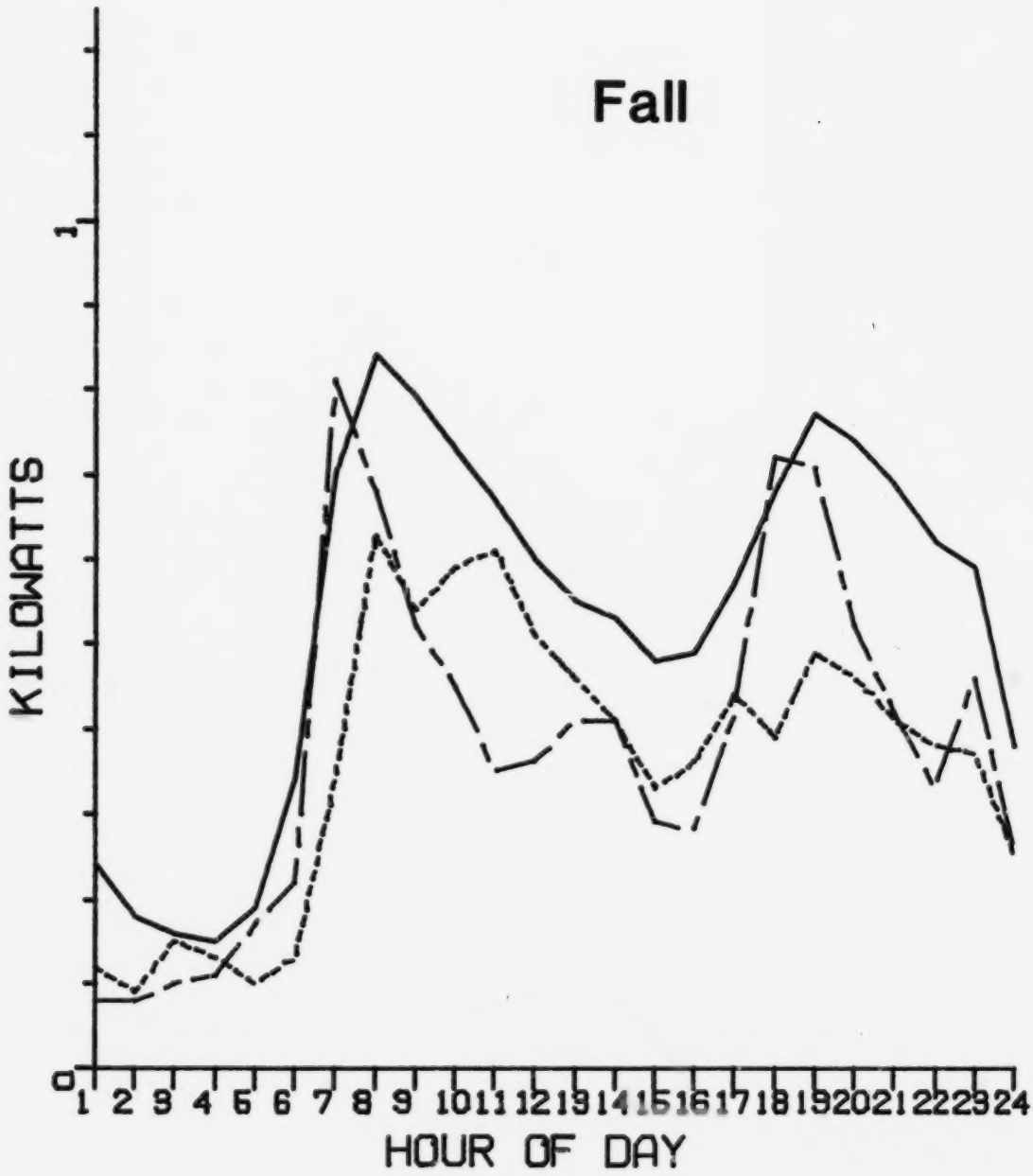

Figure 5

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HEAT PUMP WATER HEATER VS STANDARD WATER HEATER

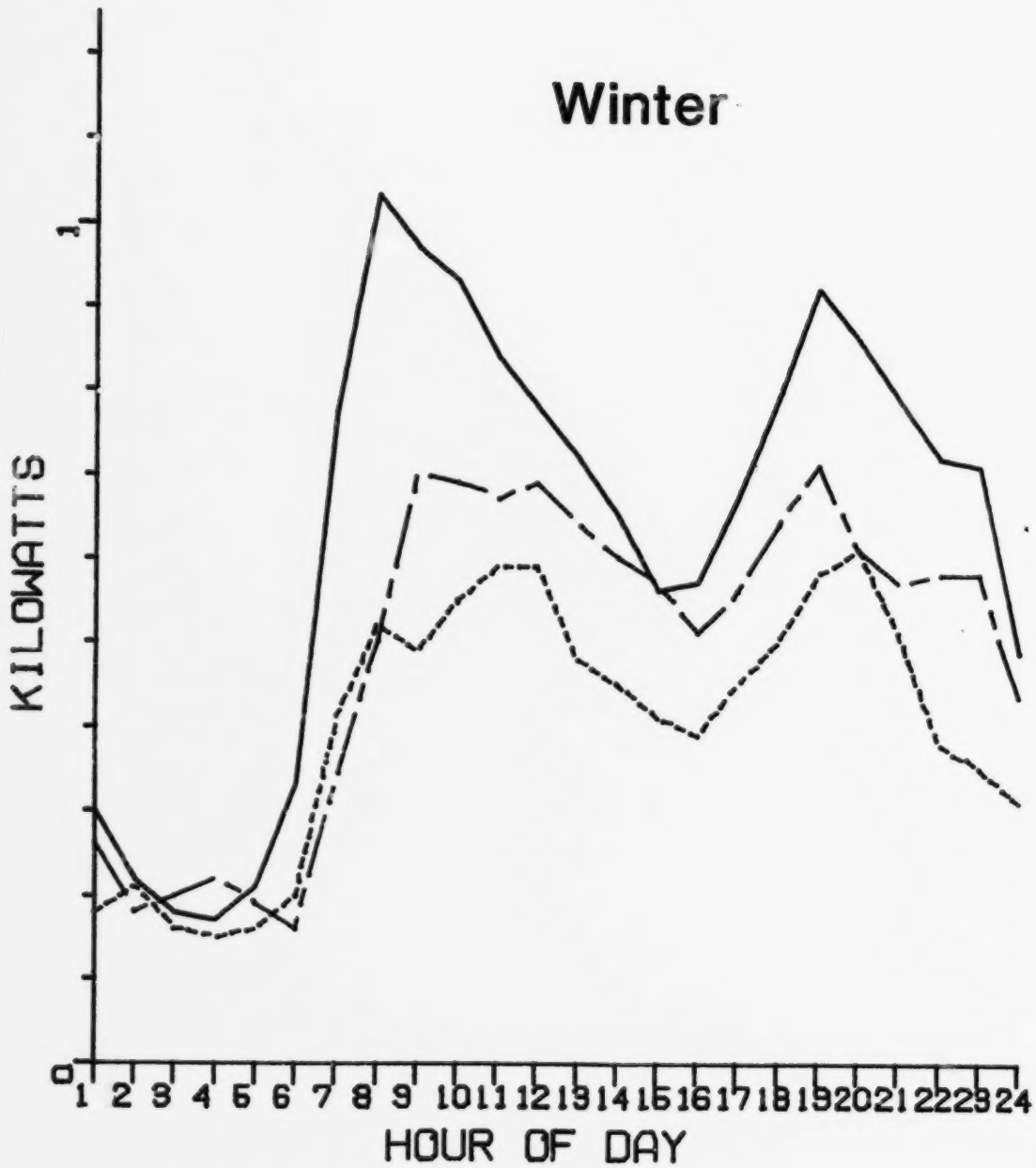

Figure 6

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Erratum

Figure 7 on page 21 should be replaced with this revision.

HEAT PUMP WATER HEATER VS STANDARD WATER HEATER

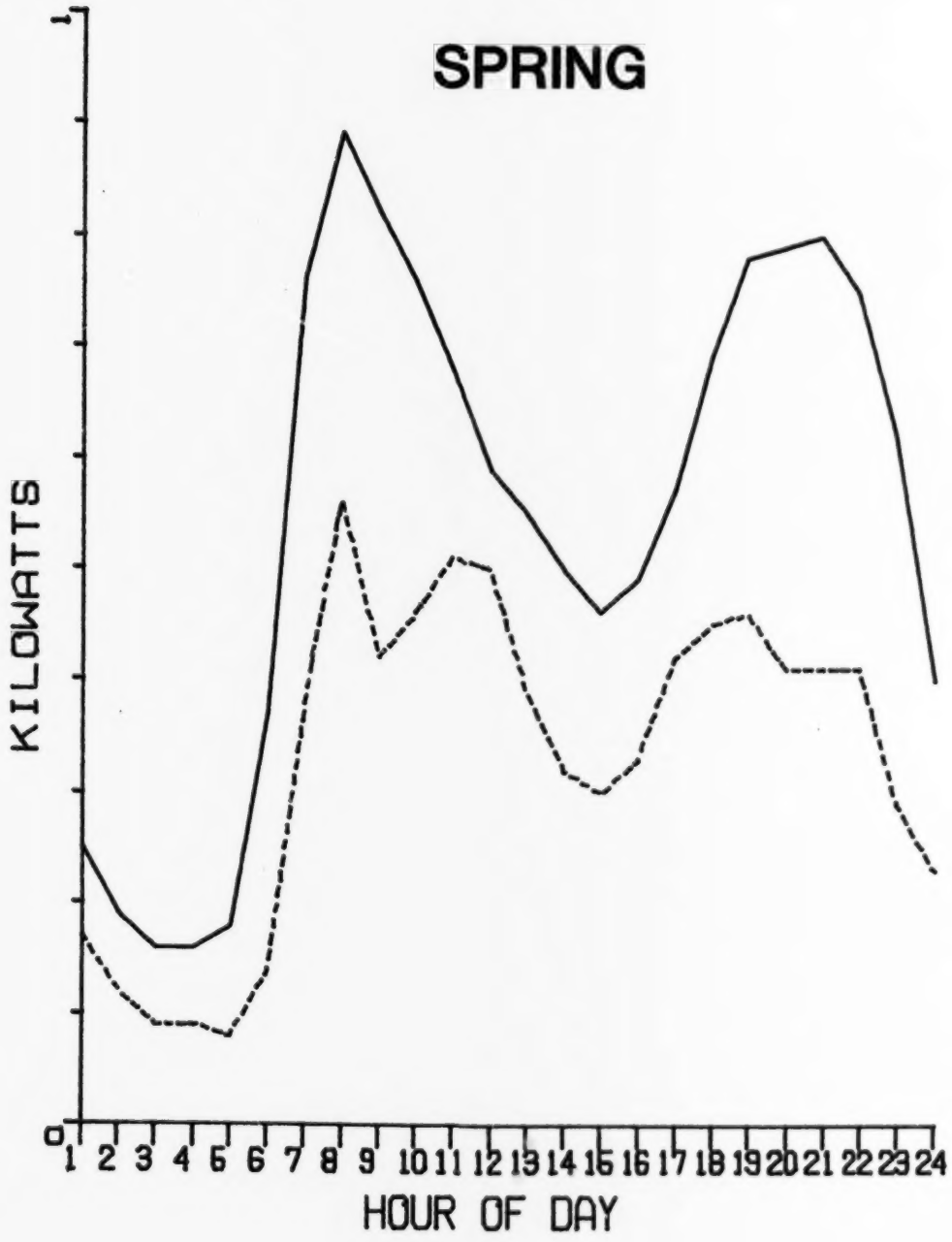

Figure 7

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HEAT PUMP WATER HEATER VS TOTAL HOME LOAD E-TECH

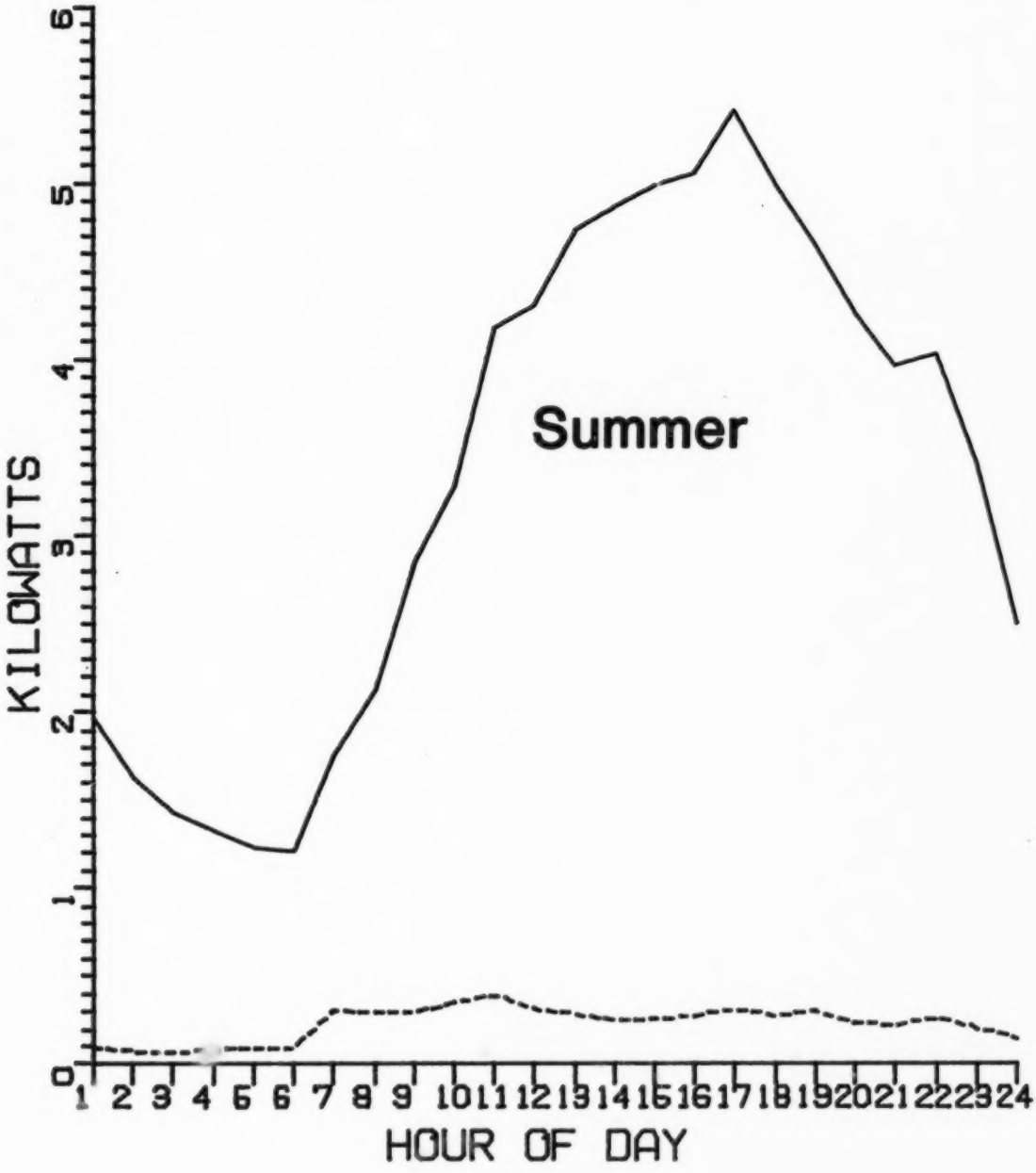

Figure 8

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HEAT PUMP WATER HEATER VS TOTAL HOME LOAD EUS

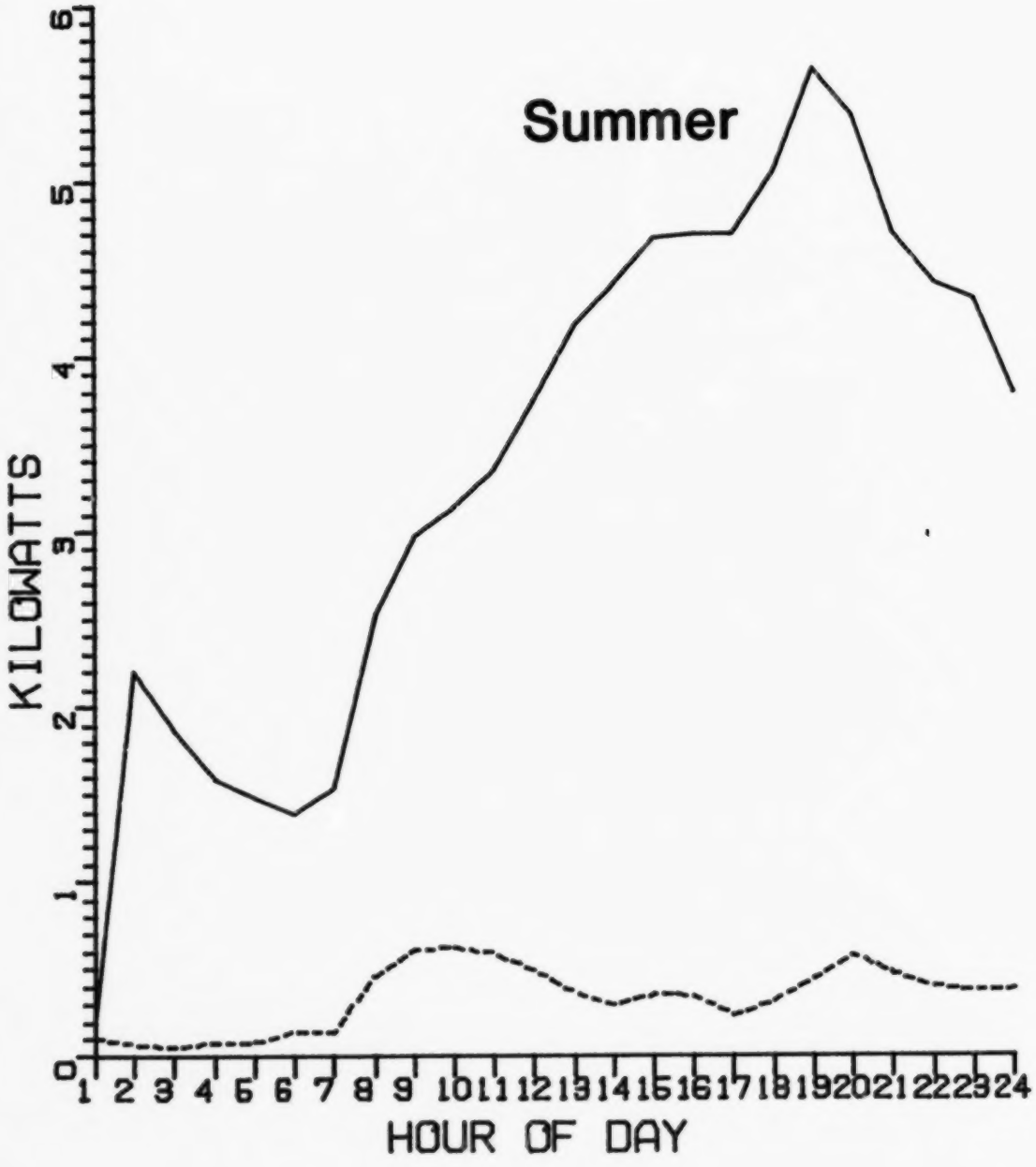

Figure 9

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HEAT PUMP WATER HEATER VS TOTAL HOME LOAD E-TECH

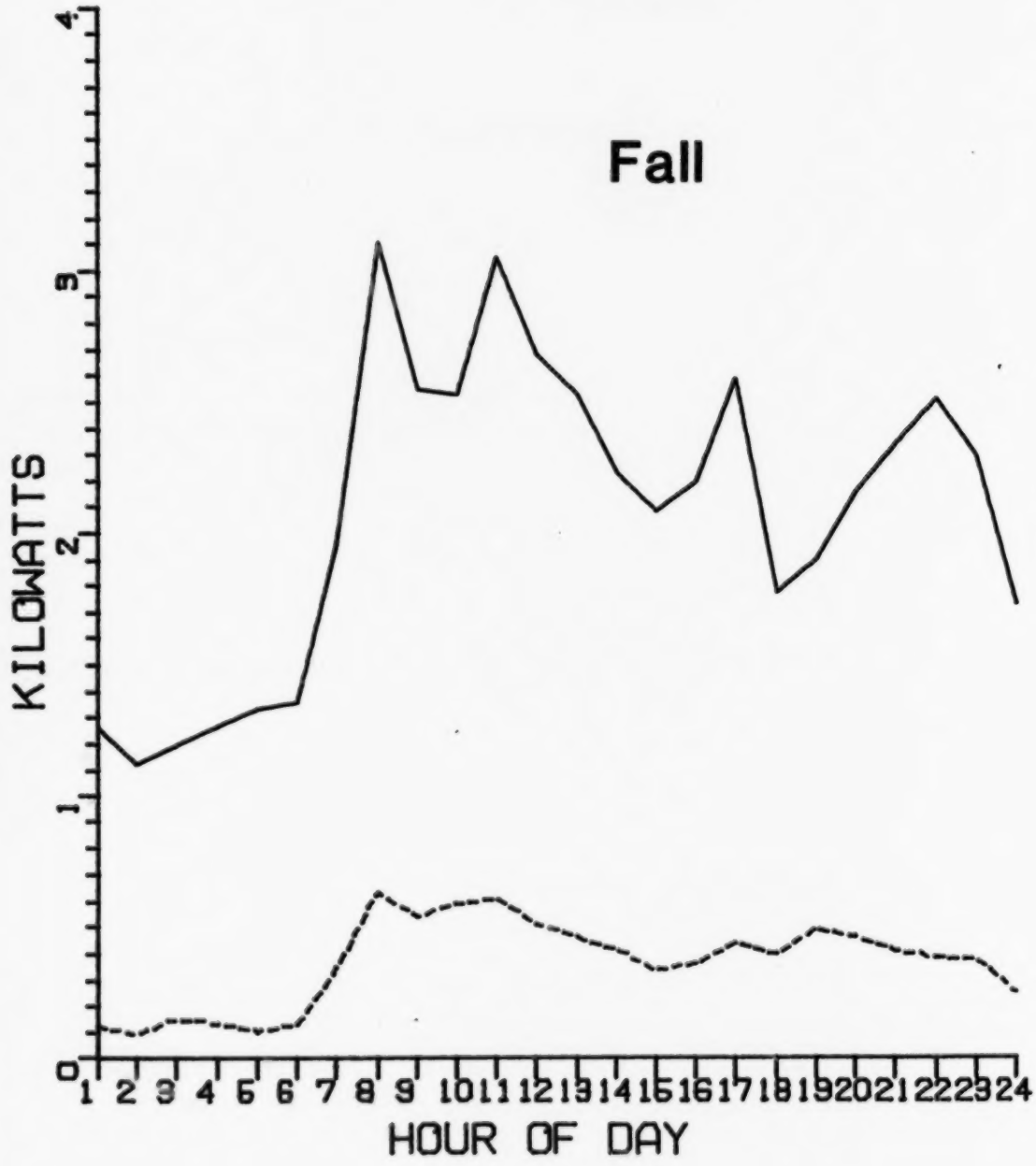

Figure 10

BEST DOCUMENT AVAILABLE

HEAT PUMP WATER HEATER VS TOTAL HOME LOAD EUS

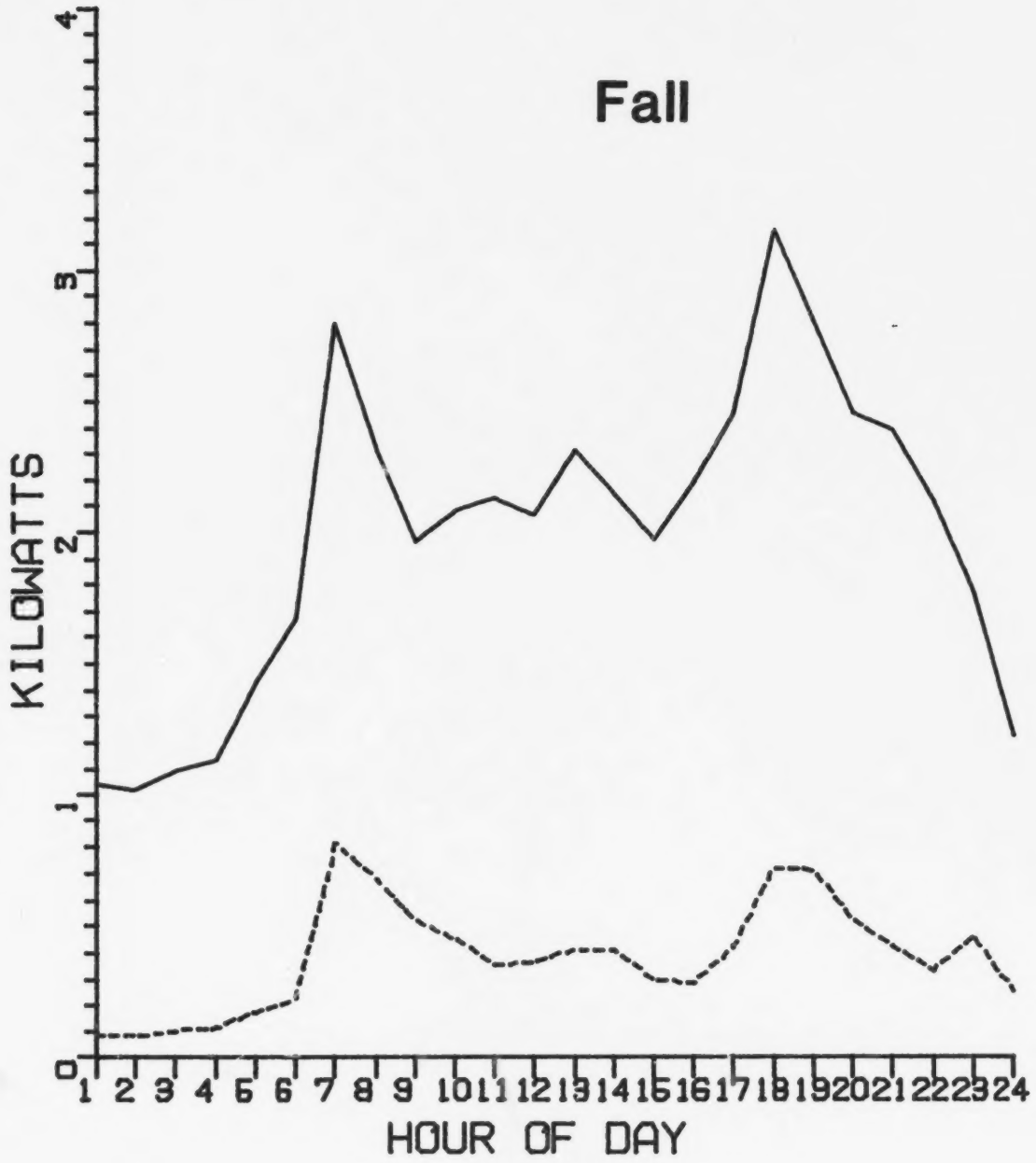

Figure 11

BEST DOCUMENT AVAILABLE

HEAT PUMP WATER HEATER VS TOTAL HOME LOAD E-TECH

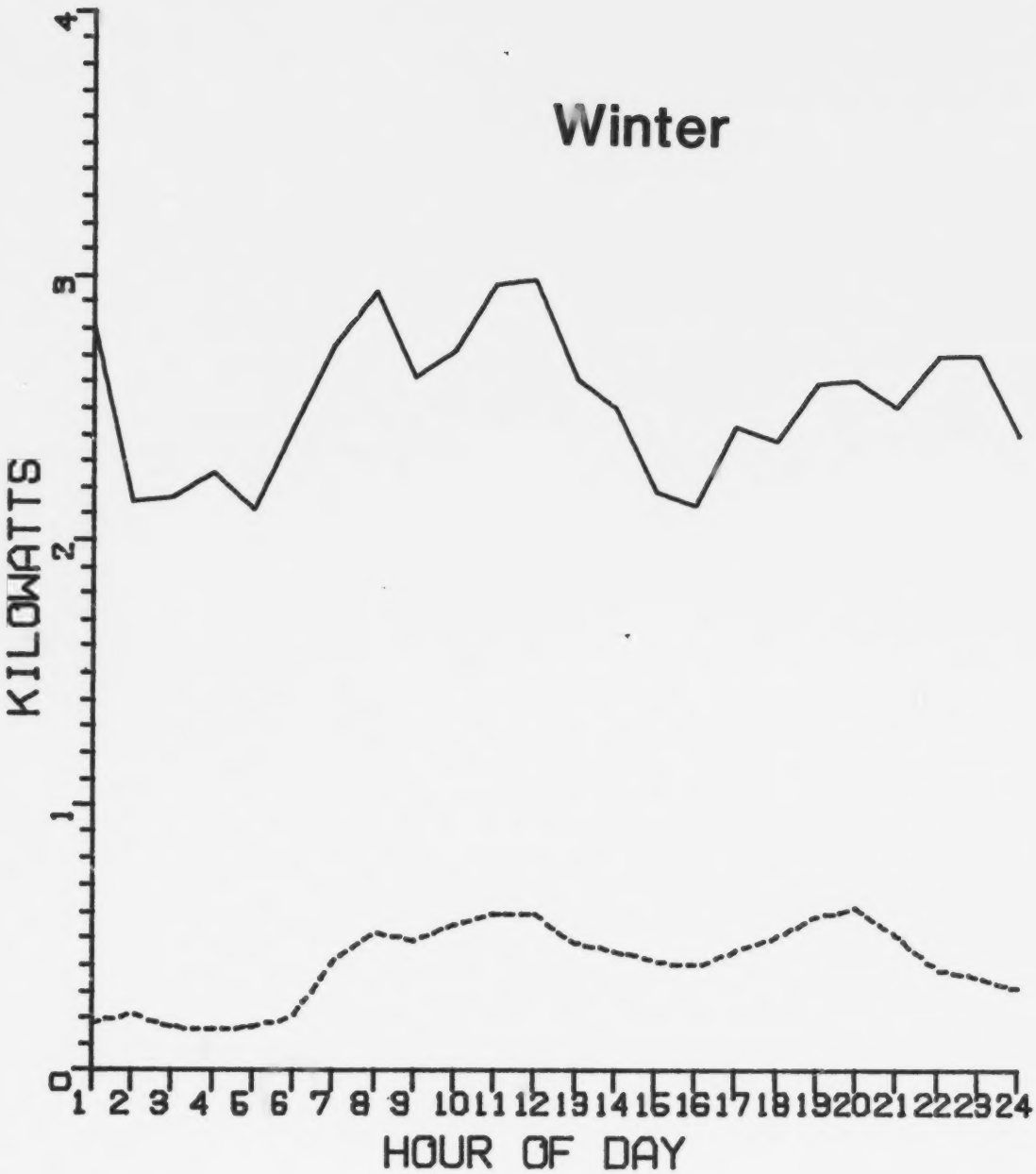

Figure 12

BEST DOCUMENT AVAILABLE

HEAT PUMP WATER HEATER VS TOTAL HOME LOAD EUS

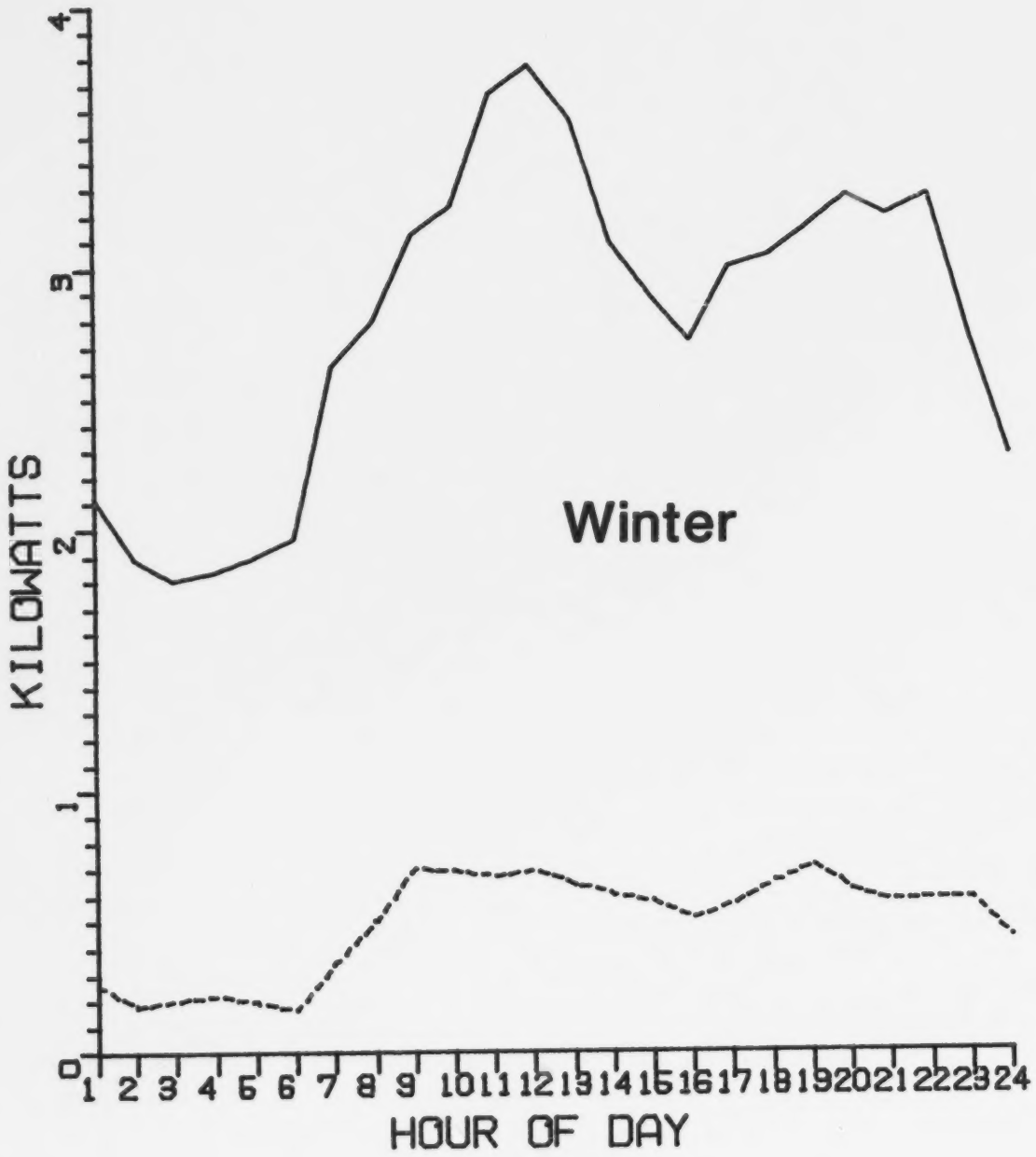

Figure 13

_____TOTAL HOME
----------HPWH

BEST DOCUMENT AVAILABLE

HEAT PUMP WATER HEATER VS TOTAL HOME LOAD E-TECH

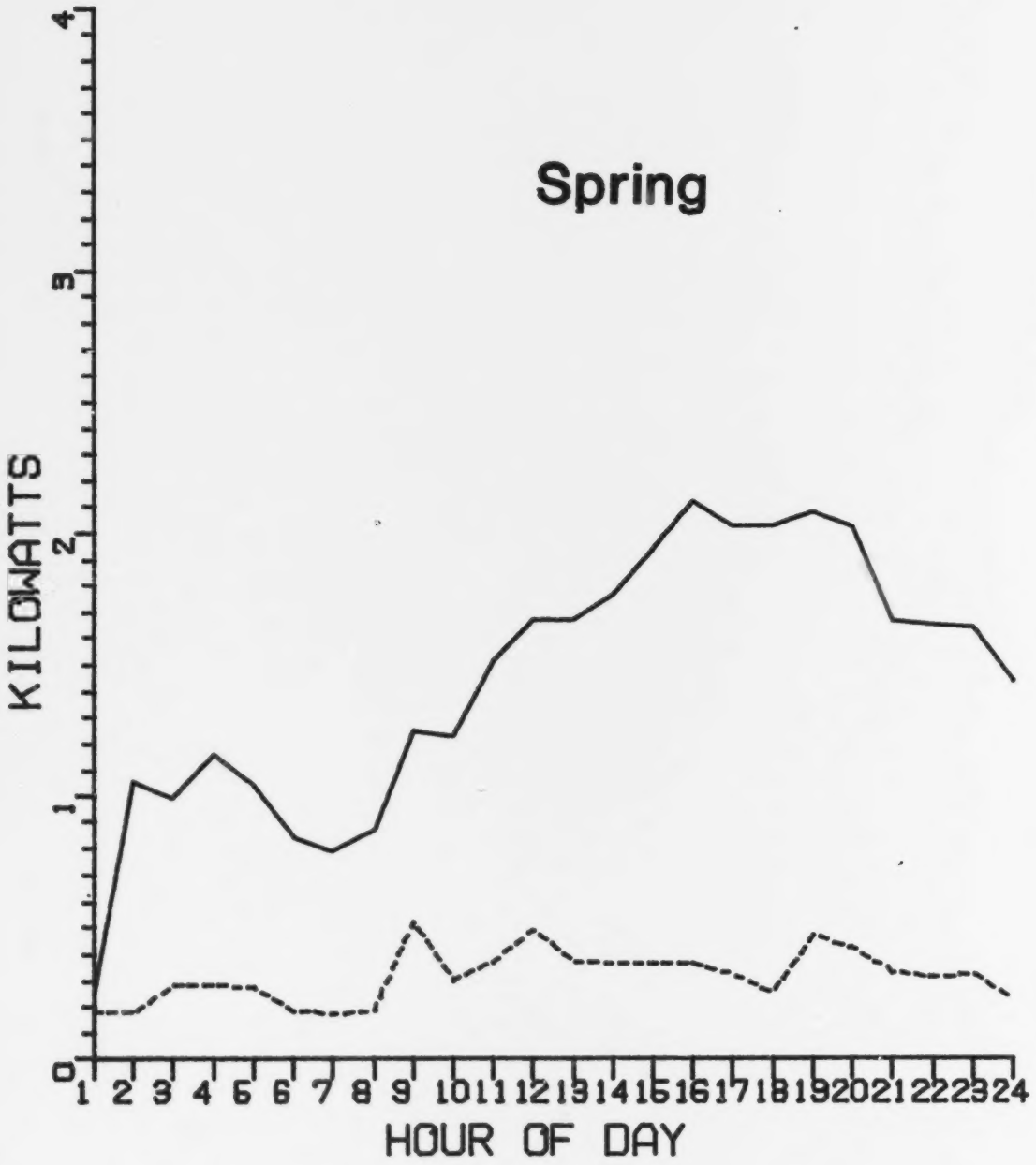

Figure 14

BEST DOCUMENT AVAILABLE

HEAT PUMP WATER HEATER VS TOTAL HOME LOAD EUS

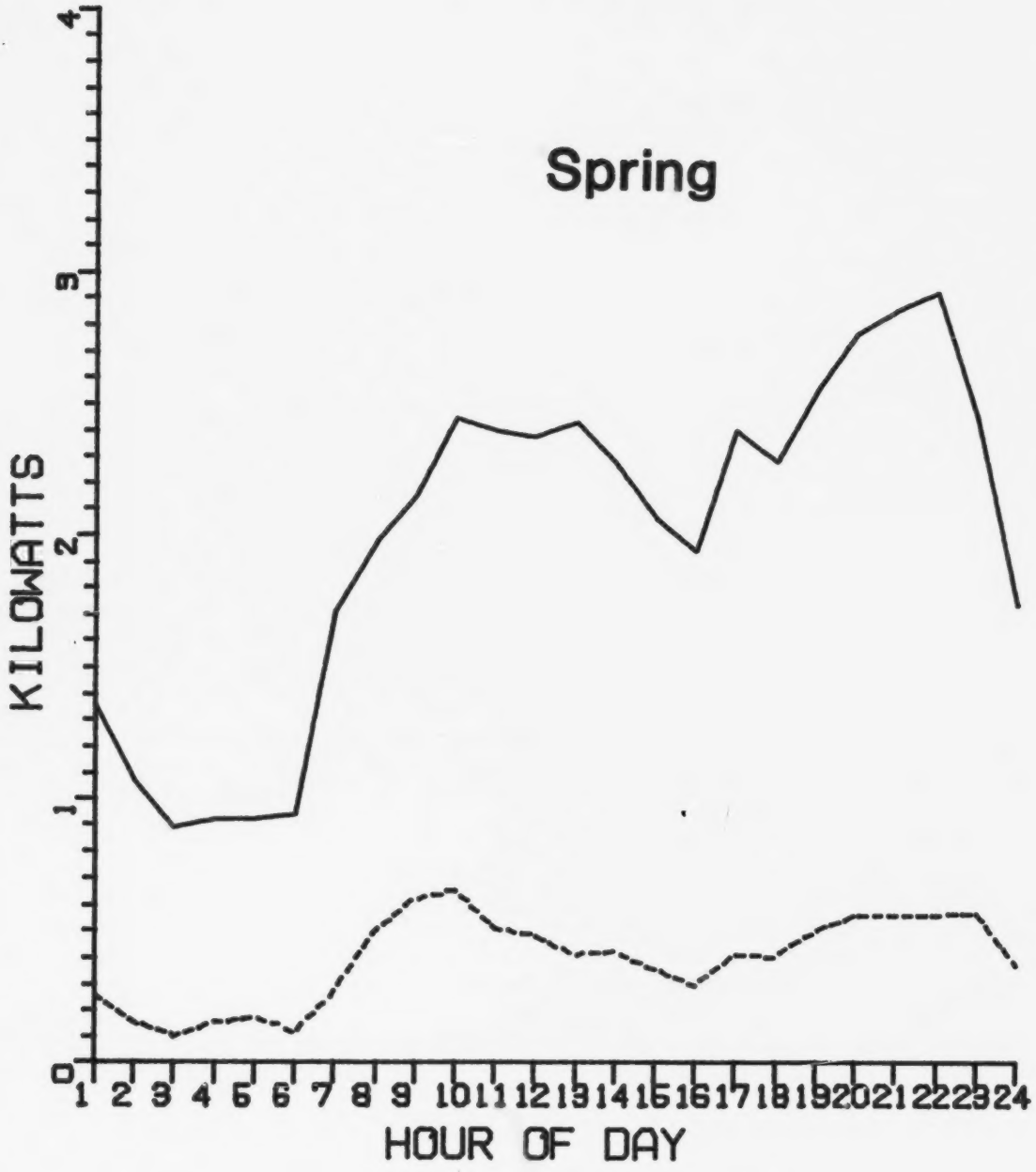

Figure 15

BEST DOCUMENT AVAILABLE

These graphs allow for load comparisons between the two types of water heaters. The load curves for water heater demand appeared to have two peaks which correspond to the general TVA system load curve. Obviously, the heat pump water heaters reduce overall power requirements. However, the load reduction percentage varies with time of day. Figures 8 through 15 show the comparison of the heat pump water heater load to the total home load.

These graphs indicate that the heat pump water heaters provide load reductions over conventional water heaters during most time periods.

Examination of the 5 heat pump water heater households used for this analysis revealed that one adult was usually in each home during the weekday. This could explain the larger than standard electrical load demanded by the heat pump units during the midday hours, if such household activities as dish and clothes washing were conducted around the noon hour. A sample size of 5 is small and may not represent the behavorial patterns of the general population. It is hoped that the data obtained from the resistance water heater users does reflect more normal weekday hot water usage habits (refer to section 2.6.2).

The graphs indicate that heat pump water heaters would most likely reduce electrical demand during the two daily TVA system peaks. This phenomenon could contribute to an overall smoothing of the TVA load curve if heat pump water heaters were put into more general use. However, more data and extensive research is needed before this conclusion can be drawn.

3.3 Consumer Acceptance:

Information concerning satisfaction and acceptance of heat pump water heaters was gathered through informal discussions with the consumers. These discussions were conducted by the Russellville Electric Board representative.

Complaints and negative comments were traced to equipment malfunctions which have been repaired. After adjustments were made to correct the malfunctioning units, the homeowners expressed satisfaction with these units. Only in the case of the EUS retrofit unit did the consumer request early removal of the heat pump water heater.

One housewife stated that she had run out of hot water twice. However, on both occasions the family took several showers and washed a large load of clothes in a short time period. The housewife remarked that her conventional water heater had failed to meet the demand in similar situations.

Two homeowners indicated they could detect a decrease in their electric bills. All the homeowners expressed an interest in the savings performance of their test equipment.

Excluding the consumer with the EUS retrofit unit, the 9 remaining participants voiced no complaints with respect to water temperatures, recovery rates, or operation of the units. Noise levels have been acceptable in all cases but one. The one noise complaint was due to a unit which was low on refrigerant after developing a system leak. After the unit was repaired and recharged, the noise problem was eliminated.

The best gauge of customer response to the units in this test is the fact that 8 of the 9 full-term test participants elected to purchase their units at the conclusion of the test. In accordance with the contract with all the participants, homeowners with EUS units chose to purchase the test units for $200 and those with E-Tech units paid $100 to keep their units. The one E-Tech unit that was not purchased had been removed from the test early because the family moved to a new home where the location of the water heater precluded the use of the heat pump water heater. At the conclusion of the test, the house was unoccupied and the owner chose not to purchase the test unit.

3.4 Consumer Economics:

The economic benefits to the typical test participant were estimated from the energy savings determinations. Using an average cost per kilowatthour of 4.217 cents, the monthly and yearly savings were calculated. In order to put the heat pump water heaters' yearly and monthly savings into proper economic perspective, calculations were made to determine the respective simple payback periods. The payback calculations utilized the incremental cost of each heat pump water heater beyond the cost of a standard resistance water heater as the cost being repaid by the savings. Table 2 depicts the results of the monthly and yearly savings and the payback calculations.

E-Tech units are designed to be installed by the do-it-yourself homeowner and contain the necessary materials. Therefore, installation costs are considered negligible. A brief survey revealed the cost to install an EUS system averages $100 which is about the same for installing a conventional resistance water heater. This is expected because the EUS unit is self-contained and all that is required are the appropriate wiring and piping connections.

3.5 Applications and Installation Location:

Both units provided savings and reasonable payback periods but have different applications. EUS units are best suited to situations where

Table 2

DOLLAR SAVINGS AND PAYBACK PERIODS

Dollar Savings*

	EUS	E-Tech
Savings/Month	$ 11.43	$ 11.26
Savings/Year	$137.16	$135.12

Pay Periods

EUS		E-Tech
$1,000 (82-gallon model) -250 (conventional water heater)		$750 (requires existing water heater)
$ 750		
Simple Payback	5.5 years	5.6 years

*The above projected savings are based on actual water consumption. In the test, the consumers with EUS units used more water than those with E-Tech units. A slightly different comparison results if consumers are assumed to use equal amounts of hot water. Assuming that a typical customer in the TVA service area used 64.3 gallons of hot water per day heated through an 80 degree Fahrenheit rise, anticipated savings would be as follows:

	EUS	E-Tech
Savings/Month	$ 8.92	$ 10.96
Savings/Year	$107.04	$131.52

the purchase of a new water heater is appropriate. This market consists of new home and replacement of failed equipment applications. In these instances, the inclusion of a storage tank to make a total system is important.

The E-Tech heat pump water heater is more suited for a retrofit application. Because the unit must be combined with an existing tank, it is better for converting existing electric units to heat pump operation. E-Tech units are shipped with all the needed hardware for a consumer to do the installation and keep the costs to a minimum.

For either type of installation, the location of the heat pump water heater is critical. These units should not be installed in conditioned space. However, they should also not be located in space where the temperature falls below 45 degrees Fahrenheit. Areas segregated from the conditioned space, yet receiving waste heat from the conditioned space, are the ideal locations for heat pump water heaters. Suitable locations for the units are basements, crawlspaces (outside vents should be closed in winter), and garages where heat is lost from the conditioned space. Adequate air volume is important to ensure a sufficient supply of energy-laden air.

An alternative installation is possible in which the units are operated only during nonheating months. This reduces the savings of the unit but allows the unit to be installed in a conditioned area. Benefit is derived from the cooling and dehumidification effect of the unit during operation. Switching circuitry would provide the means of changing from resistance to heat pump operation. This type of installation is more expensive to install and more complicated for the consumer.

4. REVIEW OF HEAT PUMP WATER HEATER TESTS

4.1 Nationwide Interest:

The number of utilities investigating heat pump water heaters has expanded since the beginning of the TVA field test. The list of current manufacturers has increased and others are developing units to enter the heat pump water heater market.

On April 10, 1980, a workshop on heat pump water heaters was sponsored by TVA and DOE to gather responses and collect information from utilities across the country that were testing heat pump water heaters. Also, the following four manufacturers of heat pump water heaters made presentations:

E-Tech, Incorporated
Atlanta, Georgia

Energy Utilization Systems, Incorporated
Pittsburgh, Pennsylvania

Fedders, Incorporated
Edison, New Jersey

Northrup, Incorporated
Hutchins, Texas

Representatives attended from 23 utilities. Various representatives made presentations about their tests of heat pump water heaters. Such presentations generally described problems and results similar to those of TVA. In addition, specific performance data from the other tests with E-Tech and EUS units generally verify the current TVA findings.

Below is a summary of results found by other utilities.

Lee County Electric Cooperative

One TEMCOR unit installed in a 6 foot by 10 foot utility room - energy savings 10 to 15 percent

Three TEMCOR units installed in garages - energy savings 20 to 45 percent

Test period - November 1979 to March 1980

Eastern Iowa Light and Power Cooperative

One TEMCOR unit installed in a new home - 9 gallons of hot water/kWh*

One TEMCOR unit installed in a basement - 5.7 gallons of hot water/kWh*

Test period - November 1979 to March 1980

*Refer to the Appendix for TVA's gallons/kWh findings.

Potomac Edison

One TEMCOR unit tested from August 1979 to March 1980.

	Percent Energy Savings
August 1979	49
September 1979	48
October 1979	42
November 1979	42
December 1979	40
January 1980	36
February 1980	36
March 1980	37

One E-Tech unit tested from November 1979 to March 1980.

	Percent Energy Savings
November 1979	58
December 4, 1979 - December 17, 1979	43
December 18, 1979 - January 2, 1980	6*
January 1980	33
February 1980	35
March 1980	40

*Freezing of evaporator occurred.

Habersham Electric Membership Corporation

One E-Tech unit installed in a basement - energy savings 64 percent.

Test period - May 1979 to April 1980.

4.2 Summary of TVA Evaluation:

After 23 months of data collection, the TVA Heat Pump Water Heater Field Test produced information concerning the performance and reliability of the two types of test units. Although the information came from a small sample, it indicated that heat pump water heaters are a potentially important load management and conservation tool.

The test data revealed an average monthly energy savings of 271 kWh ($137.16 yearly) and 267 kWh ($135.12 yearly) for the EUS and E-Tech units, respectively. This represents a 45-percent energy savings for the EUS systems and a 52-percent energy savings for the E-Tech systems. The yearly dollar savings provided the EUS units with a payback period of 5.5 years and the E-Tech units with a 5.6-year payback period. These figures were based on current water heater prices, apply to TVA consumers, and vary as a function of water usage, electricity rates, climatic conditions, and installation parameters.

Customers were pleased with the energy-saving features of the heat pump water heaters. Recovery times appeared to meet or exceed user expectations. Operating noise was not mentioned as a drawback to the units. Other than minor design problems which the manufacturers have addressed, the heat pump water heaters were reliable. This feature contributed to the high level of consumer acceptance.

4.3 Further TVA Study:

Studies have been conducted on the economics of the heat pump water heater to the consumer and to the power system. Due to the favorable results of these studies, plans are being made to include heat pump water heaters in the package of energy measures that TVA will finance.

APPENDIX

HEAT PUMP WATER HEATER FIELD TEST

AVERAGE ANNUAL DATA ANALYSIS

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	45,645	28,507	4,890	9.3	10,281	5,391	50
2	33,103	42,556	4,749	7.0	7,500	2,751	37
3	22,993	21,650	3,049	7.5	5,648	2,599	46
4	22,903	22,104	3,690	6.2	5,700	2,010	35

E-Tech

6	27,226	24,910	2,389	11.4	6,544	4,156	64
7	57,463	27,098	3,900	14.7	11,685	7,785	67
8	11,809	21,998	2,399	4.9	3,815	1,416	37
9	17,408	19,732	2,476	7.0	4,783	2,307	48
10	23,932	27,424	2,317	7.2	6,068	2,751	45

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

6/14/79 - 7/13/79

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	2,657	2,322	248	10.7	497	249	50
2	2,403	3,048	276	8.7	458	182	40
3	1,486	1,624	164	9.1	317	153	48
4*	1,918	2,410	522	3.7	383	-139	-
5							
Total			688		1,272	584	Avg. 46

E-Tech

6	1,551	915	101	15.4	353	252	71
7	4,802	2,440	246	19.5	859	613	71
8	1,066	1,864	124	8.6	284	160	56
9	1,343	1,336	99	13.6	321	222	69
10	1,325	2,089	150	8.8	324	174	54
Total			720		2,141	1,421	Avg. 66

*This unit not included in averages.

NOTE: Savings based on 63° temperature rise.

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

7/13/79 - 8/13/79

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	3,341	2,608	254	13.2	577	323	56
2	1,778	5,376	242	7.3	348	106	30
3	1,617	1,913	168	9.6	325	157	48
4*	1,351	2,647	288	4.7	286	-2	-
5	———	———	—	———	———	—	—
Total			664		1,250	586	Avg. 47

E-Tech

6	2,001	2,058	127	15.8	407	280	69
7	5,048	3,120	241	20.9	859	618	72
8	889	2,231	110	8.1	250	140	56
9	1,417	1,657	98	14.5	322	224	70
10	1,437	2,778	157	9.2	330	173	52
Total			733		2,168	1,435	Avg. 66

*This unit not included in averages.

NOTE: Savings based on 60° temperature rise.

BEST DOCUMENT AVAILABLE

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

8/13/79 - 9/13/79

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	3,236	2,544	266	12.2	586	320	55
2	1,975	3,616	250	7.9	392	142	36
3	1,540	1,714	164	9.4	325	161	50
4	1,734	2,162	232	7.5	355	123	35
5	____	____	___	____	____	___	___
Total			912		1,658	746	Avg. 45

E-Tech

6	1,680	1,582	106	15.8	372	266	72
7	5,039	2,889	255	19.8	895	640	72
8	932	1,976	117	8.0	263	146	56
9	1,460	1,351	101	14.5	339	238	70
10	1,365	2,277	157	8.7	330	173	52
Total			736		2,199	1,463	Avg. 67

NOTE: Savings based on 63° temperature rise.

BEST DOCUMENT AVAILABLE

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

9/13/79 - 10/12/79

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	2,609	1,677	258	10.1	540	282	52
2	2,484	1,982	286	8.7	519	233	45
3	1,487	1,203	170	8.7	346	176	51
4	1,546	1,225	246	6.3	356	110	31
5*	948	1,125	774	1.2	252	-522	-
Total			960		1,761	801	Avg. 45

E-Tech

6	2,325	1,026	169	13.8	517	348	67
7	4,983	1,669	278	17.9	984	706	72
8	861	1,271	129	6.7	269	140	52
9	1,530	896	114	13.4	379	265	70
10	1,526	1,915	164	9.3	385	221	57
Total			854		2,534	1,680	Avg. 66

*This unit not included in averages.

NOTE: Savings based on 71° temperature rise.

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

10/12/79 - 11/13/79

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	3,109	1,883	326	9.5	695	369	53
2	2,177	2,805	320	6.8	513	193	38
3	1,812	1,671	234	7.7	442	208	47
4	1,735	1,353	246	7.1	427	181	42
5	____	____	____	____	____	____	____
Total			1,126		2,077	951	Avg. 46

E-Tech

6	1,983	1,362	172	11.5	501	329	66
7	5,584	1,669	368	15.2	1,211	843	70
8	676	1,402	166	4.1	252	86	34
9	1,585	1,318	155	10.2	424	269	63
10	2,270	629	303	7.5	563	260	46
Total			1,164		2,951	1,787	Avg. 61

NOTE: Savings based on 80° temperature rise.

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

11/13/79 - 12/13/79

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	3,267	2,163	388	8.4	798	410	51
2	2,911	3,784	410	7.1	721	311	43
3	1,778	1,771	242	7.3	474	232	49
4	1,846	1,340	312	5.9	489	177	36
5	———	———	———	——	———	———	——
Total			1,352		2,482	1,130	Avg. 46

E-Tech

6	2,141	1,919	197	10.9	579	382	66
7	3,973	1,493	379	10.5	983	604	61
8	522	1,515	210	2.5	233	23	10
9	1,507	2,575	171	8.8	441	270	61
10	2,420	2,390	379	6.4	646	267	41
Total			1,336		2,882	1,546	Avg. 54

NOTE: Savings based on 89° temperature rise.

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

12/13/79 - 1/14/80

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	5,465	3,239	690	7.9	1,382	692	50
2	3,129	5,349	536	5.8	829	293	35
3	2,240	1,970	332	6.7	618	286	46
4	1,983	1,500	144	13.8	558	414	74
5	———	———	———	———	———	———	—
Total			1,702		3,387	1,685	Avg. 50

E-Tech

6	2,979	2,657	338	8.8	819	481	59
7	5,444	1,826	547	10.0	1,409	862	61
8	1,182	1,510	202	5.9	400	198	50
9	1,658	1,030	274	6.1	507	233	46
10*	2,180	3,393	661	3.3	636	-25	-
Total			1,361		3,135	1,774	Avg. 57

*This unit not included in averages.

NOTE: Savings based on 97° temperature rise.

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

1/14/80 - 2/13/80

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	4,041	3,102	496	8.1	1,075	579	54
2*	No Valid Data Available						
3	1,726	2,039	284	6.1	509	225	44
4	2,050	1,696	462	4.4	588	126	21
5	____	____	____	____	____	____	____
Total			1,242		2,172	930	Avg. 43

E-Tech

6	2,370	2,832	292	8.1	693	401	58
7*	No Data Due to Freeze-Up of Unit						
8	1,012	1,568	186	5.4	367	181	49
9	1,541	2,297	294	5.2	490	196	40
10*	1,825	3,341	625	2.9	565	-59	-
Total			772		1,550	778	Avg. 50

*This unit not included in averages.

NOTE: Savings based on 100° temperature rise.

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

2/12/80 - 3/13/80

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	4,211	2,451	534	7.9	1,085	551	51
2*			No Valid Data Available				
3	1,693	1,810	248	6.8	489	241	49
4	1,785	1,563	286	6.2	511	225	44
5	———	———	———	———	———	———	—
Total			1,068		2,085	1,017	Avg. 49
			E-Tech				
6	2,585	2,328	301	8.6	726	425	59
7			No Data				
8	1,167	1,438	190	6.1	396	206	52
9	1,342	1,746	221	6.1	432	211	49
10	1,932	2,495	562	3.4	578	16	3
Total			1,274		2,132	858	Avg. 40

*This unit not included in averages.

NOTE: Savings based on 97° temperature rise.

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

3/13/80 - 4/14/80

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	4,929	2,357	568	8.7	1,159	591	51
2			No Valid Data Available				
3	1,932	1,751	252	7.7	508	256	50
4	2,265	1,712	320	7.1	580	260	45
5	———	———	———	———	———	———	—
Total			1,140		2,247	1,107	Avg. 49
			E-Tech				
6	2,815	2,838	295	9.5	726	431	59
7			No Data				
8	1,405	1,837	265	5.3	425	160	38
9	1,357	1,370	228	6.0	409	181	44
10	2,423	2,079	394	6.1	646	252	39
Total			1,182		2,206	1,024	Avg. 46

NOTE: Savings based on 89° temperature rise.

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

4/14/80 - 5/15/80

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	4,069	1,791	466	8.7	883	417	47
2			No Valid Data Available				
3	1,765	1,412	254	6.9	433	179	41
4	1,991	1,199	288	6.9	477	189	40
5	———	———	———	———	———	———	———
Total			1,088		1,793	785	Avg. 44

E-Tech

6	2,500	-	227	11.0	602	375	62
7	4,677	1,514	373	12.5	1,033	660	64
8	1,092	1,246	208	5.3	333	125	38
9	1,330	933	182	7.3	374	192	51
10	2,150	1,401	247	8.7	540	293	54
Total			1,237		2,882	1,645	Avg. 57

NOTE: Savings based on 80° temperature rise.

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

5/15/80 - 6/15/80

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWn	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	3,305	2,217	326	10.1	661	335	51
2*	2,279	2,756	211	10.8	483	272	56
3	1,904	1,870	238	8.0	418	180	43
4	1,939	1,924	248	7.8	424	176	42
5	———	———	———	———	———	———	———
Total			1,023		1,986	963	Avg. 48

E-Tech

6	2,120	1,617	155	13.7	481	326	68
7	4,690	2,410	327	14.3	933	606	65
8	1,134	2,196	212	5.3	317	105	33
9	1,310	1,411	160	8.2	341	181	53
10	1,980	2,382	208	9.5	463	255	55
Total			1,062		2,535	1,473	Avg. 58

*This unit functioning in heat pump mode only.

NOTE: Savings based on 71° temperature rise.

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

6/14/79 - 7/13/79

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	2,720	2,743	288	9.4	506	218	43
2	2,190	5,334	291	7.5	425	134	32
3	1,640	2,259	190	8.6	340	150	44
4	1,900	2,710	184	10.3	380	196	52
5	———	———	———	———	———	———	———
Total			953		1,651	698	Avg. 42

E-Tech

6	2,300	2,873	164	14.0	468	304	65
7	3,410	2,872	224	15.2	644	420	65
8	1,090	2,850	175	6.2	288	113	39
9	1,120	1,834	115	9.7	286	171	60
10	1,530	3,315	152	10.1	355	203	57
Total			830		2,041	1,211	Avg. 59

NOTE: Savings based on 63° temperature rise.

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

7/18/80 - 8/21/80

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1							
2							
3			No Data Available Due to Conversion of Units to Total Heat Pump Operation				
4							
5							
Total							

E-Tech

6	2,270	2,917	149	15.2	447	298	67
7	4,061	3,721	257	15.8	715	458	64
8	1,230	3,653	205	6.0	300	95	32
9	1,331	2,345	138	9.6	309	171	55
10	2,700	4,183	237	11.4	516	279	54
Total			986		2,287	1,301	Avg. 57

NOTE: Savings based on 60° temperature rise.

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

8/21/80 - 9/18/80

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	2,199	2,143	174	12.6	426	252	59
2	1,920	4,520	242	7.9	383	141	37
3	1,448	1,864	154	9.4	311	157	50
4	1,500	2,311	184	8.2	319	135	42
5	____	____	___	____	____	___	___
Total			754		1,439	685	Avg. 48

E-Tech

6	1,720	2,184	118	14.6	379	261	69
7	4,139	3,200	270	15.3	757	487	64
8	460	1,887	100	4.6	191	91	48
9	919	1,609	102	9.0	255	153	60
10	1,580	1,993	132	12.0	363	231	64
Total			722		1,945	1,223	Avg. 63

NOTE: Savings based on 63° temperature rise.

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

9/18/80 - 10/16/80

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	2,680	1,436	229	11.7	553	324	59
2	2,940	2,914	393	7.5	598	205	34
3	2,000	1,714	242	8.3	435	193	44
4	1,690	1,449	323	5.2	381	58	15
5	____	____	____	____	____	____	____
Total			1,187		1,967	780	Avg. 40

E-Tech

6	2,210	1,578	175	12.6	497	322	65
7	3,450	917	235	14.7	718	483	67
8	1,070	1,917	198	5.4	305	107	35
9	1,360	1,084	157	8.7	350	193	55
10	1,430	1,469	182	7.9	368	186	51
Total			947		2,238	1,291	Avg. 58

NOTE: Savings based on 71° temperature rise.

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

10/16/80 - 11/26/80

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	4,991	2,414	493	10.1	1,063	570	54
2	5,780	4,141	470	12.3	1,217	747	61
3	2,266	1,832	300	7.6	531	231	43
4	2,040	1,719	425	4.8	486	61	13
5	____	____	____	____	____	____	____
Total			1,688		3,297	1,609	Avg. 49

E-Tech

6	3,020	2,527	298	10.1	704	406	58
7	7,740	1,874	550	14.1	1,632	1,082	66
8	1,065	2,065	269	4.0	328	59	18
9	2,149	1,826	307	7.0	534	227	43
10	2,506	2,141	325	7.7	609	284	47
Total			1,749		3,807	2,058	Avg. 54

NOTE: Savings based on 80° temperature rise.

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

11/26/80 - 1/06/81

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	6,109	3,768	709	8.6	1,415	706	50
2	2,142	4,749	791	2.7	553	-238	-43
3	2,964	2,697	439	6.8	732	293	40
4	2,160	3,157	366	5.9	557	191	34
5	———	———	———	——	———	---	——
Total			2,305		3,257	952	Avg. 29

E-Tech

6	Unit Disconnected Due to Malfunction						
7	Homeowner Moved; Unit Inactive						
8	1,055	2,138	281	3.8	349	68	19
9	1,796	2,976	395	4.5	504	109	22
10	2,874	3,542	489	5.9	744	255	34
Total			1,165		1,597	432	Avg. 27

NOTE: Savings based on 89° temperature rise.

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

1/06/81 - 2/06/81

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	4,020	2,933	504	8.0	1,040	536	52
2	3,118	2,757	571	5.5	826	255	31
3	2,170	2,101	346	6.3	602	256	43
4	1,940	2,735	327	5.9	547	220	40
5	———	———	———	——	———	———	——
Total			1,748		3,015	1,267	Avg. 42

E-Tech

6	Unit Removed Due to Malfunction						
7	Homeowner Moved; Unit Inactive						
8	1,010	1,699	249	4.1	359	110	31
9	1,410	2,489	347	4.1	448	101	23
10	2,340	3,210	407	5.7	674	267	40
Total			1,003		1,481	478	Avg. 32

NOTE: Savings based on 97° temperature rise.

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

2/06/81 - 3/10/81

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	3,810	2,322	449	8.5	990	541	55
2	3,191	2,464	521	6.1	844	323	38
3	2,070	1,758	345	6.0	578	233	40
4	1,580	2,038	313	5.0	462	149	32
5							
Total			1,628		2,874	1,246	Avg. 43

E-Tech

6			Unit Removed				
7			Unit Removed				
8	1,160	1,730	288	4.0	395	107	27
9	1,400	1,670	327	4.3	446	119	27
10	2,090	2,372	341	6.1	615	274	45
Total			956		1,456	500	Avg. 34

NOTE: Savings based on 97° temperature rise.

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

3/10/81 - 4/13/81

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	4,730	2,074	496	9.5	1,116	620	55
2	3,379	2,372	504	6.7	822	318	39
3	2,610	1,443	298	8.7	655	357	54
4	2,580	1,935	525	4.9	649	124	19
5							
Total			1,823		3,242	1,419	Avg. 44

E-Tech

6			Unit Removed				
7			Unit Removed				
8	1,150	1,666	280	4.1	370	90	24
9	1,570	1,370	308	5.1	455	147	32
10	1,890	1,534	281	6.7	531	250	47
Total			869		1,356	487	Avg. 36

NOTE: Savings based on 89° temperature rise.

BEST DOCUMENT AVAILABLE

HEAT PUMP WATER HEATER FIELD TEST

MONTHLY DATA ANALYSIS

4/13/81 - 5/18/81

EUS

Customer	Gallons	House kWh	Heat Pump Water Heater kWh	Gal/kWh	Estimated kWh Normally	Estimated kWh Savings	Percent Savings
1	4,380	1,700	395	11.1	944	549	58
2	3,100	2,321	414	7.5	694	280	40
3	2,090	1,471	271	7.7	496	225	45
4	2,000	1,271	411	4.8	479	68	14
5	____	____	____	____	____	____	—
Total			1,491		2,613	1,122	Avg. 43

E-Tech

6			Unit Removed				
7			Unit Removed				
8	1,030	670	235	4.4	321	86	27
9	1,480	1,052	247	5.9	403	156	39
10	2,119	1,512	262	8.1	534	272	51
Total			744		1,258	514	Avg. 41

NOTE: Savings based on 80° temperature rise.